Instrument Panel Design

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This project focused on the design and implementation of an Electronic Flight Instrument System for a home built experimental aircraft known as a CH-701. Older aircraft use manual gauges and dials based on varying internal instruments such as gyro's and the like but many of these traditional instruments to a singular GUI displaying multiple instruments data at one time. These devices are aimed at helping the pilot stay more alert and aware when flying between automatic warnings when in dangerous flying conditions / configurations as well as simplifying the instrument panel to only display what is absolutely necessary. These programs help with reaction time and response and will improve the overall safety of the flight for the pilot, passengers and ground civilians alike.

I. Introduction

The aviation industry began to really sprout around the time of the First World War, and it was just after this war that it was necessary for this industry to adapt to be more accommodating for tourism purposes to fit the needs of the consumers now that the war was over. One of the largest issues with this transition is that at the time, the tourist based aircraft were still very expensive for the current economy status. And so the race began to design a lighter, cheaper aircraft making it possible for middle class citizens to afford their own aircraft. And so designers began to stray from the required certification of such professional societies including the CAA, the governing aircraft industry association of the time. Without the necessary requirements and minimums designated by the CAA to be met, designers had more room to implement out of the box additions for production of these aircraft and new design features of the parts themselves.

One of the first new designs introduced was labeled as the 'Canard', named after the French word for duck as the public saw that the design resembled that of a duck by its lack of a tail and small design surfaces. This particular aircraft configuration was introduced by Burt Rutan around the 1950's and features a smaller forward surface in comparison to its rearward surface. An example of this canard design is shown in Figure 1.

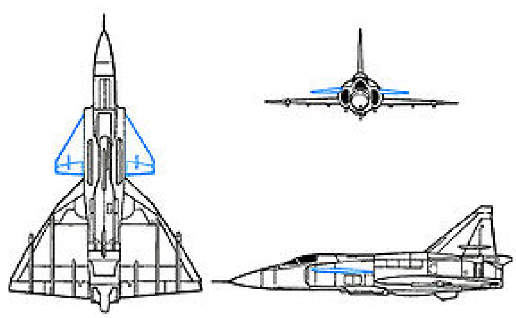

Figure 1. Example of an Aircraft with a Canard

One of its biggest contributions lent the experiment aircraft industry the concept of using composite construction. The next biggest development of experimental aircraft was the RV series designed by Richard VanGrunsven, which has proceeded to become one of the most popular of the available experimental aircraft designs still to this day, known for its fuel efficiency and speed in particular. One of these RV series aircraft can be seen in Figure 2.

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Figure 2. The RV-10, an Aircraft from the RV Series

As technology has inevitably increased over the years, the designs of these types of aircraft have turned to more advanced implementations including adaptations such as auto pilot and high level navigation systems including EFIS systems that bundle not only GPS based mapping but a majority, if not all, of the necessary gauges and instruments needed for the instrument panel of an aircraft, which the CH-701 itself uses.

In the early 1980's, Lancair International, Inc presented one of the more advanced designs of single-engine land aircraft that boasted cruise speeds that could outdo twin-engine turboprop aircraft. Although pilots have the choice to either buy an experimental aircraft kit and build it completely on their own or to buy the kit and physically make the aircraft in the factory itself with their aid during the entire process. This allows for the aircraft to still be built by the pilot but under safer supervision and to not be required to undergo the long and strenuous process of registering the aircraft by getting it certified by FAA officials. As long as the pilot completes at least more than half of the legwork of building the aircraft, these workarounds can be applied.

A majority of the calibration portion for the EFIS system merely requires the user to select what type of units they prefer for the readings to be displayed in. Users can also designate what order and set up they desire the instruments to be displayed as, more specifically which instruments they would like to be displayed on the screen at which time, a template of the instruments that are shown in sets.

When building an experimental aircraft from a kit, there are several decisions that must be made by the builder. One of the main decisions is how to build the instrument panel for the aircraft. This instrument panel must be able to relate a large amount of data about the performance and status of the aircraft to the pilot as efficiently as possible. The panel needs to be simple enough for a pilot to quickly see the data that he needs, and the amount of instrumentation will reflect the certification of the aircraft.

For a homebuilt aircraft, there are three main types of certifications: Instrument Flight Rules (IFR), Visual Flight Rules (VFR) with Night Operations, and VFR, Day Only. There are certain instruments that are necessary for night flying, but for homebuilt aircraft only flying during the day there is a minimum instrumentation as specified in FAR Part 91, Section 91.33. These instruments are mainly to call out the location, speed, and engine condition during the flight, and are laid out in a typical configuration in Figure 3.

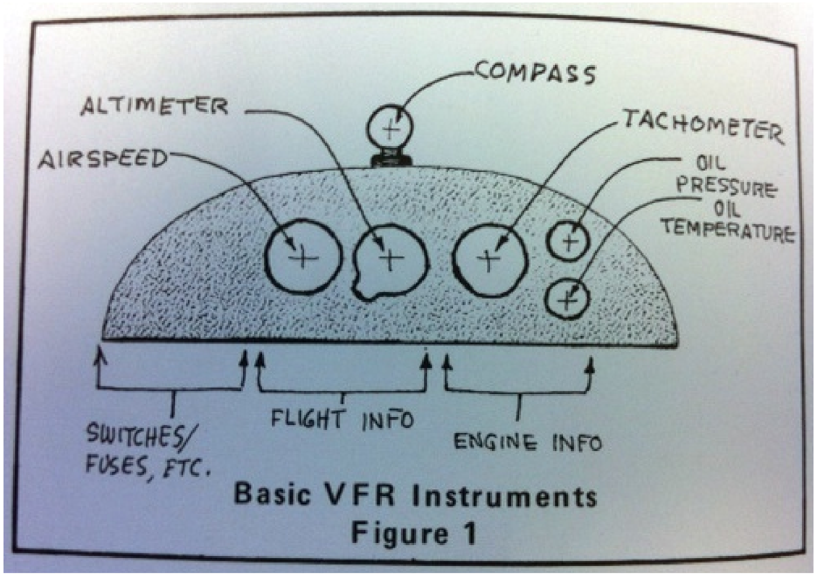

Figure 3. Basic VFR Flight Instrumentation

The minimum instrumentation called out by the FARs includes the airspeed indicator, altimeter, compass, tachometer, oil pressure gage, oil temperature gage, and fuel gage for each tank. Decreasing the amount of instrumentation to these minimums allows for a much cheaper and lighter panel. Using these instruments, a pilot can successfully manage the aircraft during the day in good weather conditions.

These various instruments allow the pilot to monitor vital performance characteristics through the use of sensors all over the aircraft. The air speed indicator, for instance, takes the difference in pressure of the pitot and static ports in the pitot tube, normally located on the wing. The altimeter gage also shares the static port pressure. This hosing, mixed in with the wiring for the panel, can create a fairly large mess behind the instrument panel. Many of the gages also need readings from the engine, leading to issues in getting sensor data from the engine to the panel. Power to the panel also traditionally comes from the engine battery, and has to be routed to the instruments as well. All this leads to the fact that to make a successful instrument panel, one must know how all the instruments interact and gather data from the rest of the aircraft.

For the Zenith CH-701 STOL aircraft, the instrument panel is fairly small, and in most cases dictates a maximum number of instruments that can be placed on the plane. With traditional instrumentation, this leads to fairly clustered panel, as seen on a CH-701 in Figure 4.

Figure 4. An Example of a CH-701 with Traditional Gages

When the radio, push-pull controls for the engine, fuel gages, fuses, and power switches are all accounted for on the panel, there is very little room left for additional instruments. Placement for easy accessibility for the pilot becomes a problem as well, where the pilot might not be able to reach or see an important instrument. These considerations led us to a simple and minimalistic instrument panel on our CH-701.

II. Design Analysis

For Cal Poly's CH-701, the main goal was to keep the aircraft cheap and simple, and to be certified for VFR Day Only, with about one hour of flight time. The professor in charge of the program, Dr. Kurt Colvin, had already obtained some instruments for the plane, such as the Flightline FL-760 radio and push-pull controls for the engine. This allowed us to focus on obtaining just the main gages for the instrument panel.

Working with Dr. Colvin, the problem of the small panel for the CH-701 was analyzed. It was concluded that a complex instrument panel with many traditional gages would be inefficient for this aircraft, and so other options were looked into. It was found that a single EFIS, or Electronic Flight Instrument System, would allow for all the primary instrumentation of the aircraft to be easily read, without taking up much space on the instrument panel. Certain EFIS systems also included many of the sensors for the engine. This demonstrated that although the single EFIS instrument was expensive, when bought in a package with engine sensors this would be cost effective as well. Sifting through all the possible options for the EFIS system, the MGL Avionics XTreme EFIS was chosen, and is shown in Figure 5.

Figure 5. MGL Avionics XTreme EFIS used as the Primary Instrument

The XTreme EFIS system included compatible components consisting of digital sensors that hook up to the EFIS, and replace any traditional analog gages. These sensors included the AHRS (Attitude/Heading Reference Sensor), the magnetometer (compass sensor), and the RDAC (Remote Data Acquisition Computer). The AHRS allows the EFIS to display the attitude, G-force, turn rate, and slip/skid of the aircraft in flight, while the magnetometer gives the magnetic heading for the aircraft, also shown on the EFIS. The RDAC allows for all the engine sensor data, such as the cylinder head temperatures, oil temperature, oil pressure, fuel flow, and the RPM of the engine to connect to the RDAC on the engine side of the firewall. Then only one bundle of wires needs to be hooked up to the EFIS to show all the engine data. The static and pitot lines containing the pressure from the pitot tube also simply connects to the back of the EFIS, giving air speed and altitude. These connections to the XTreme EFIS accessed on the back of the instrument are shown in Figure 6.

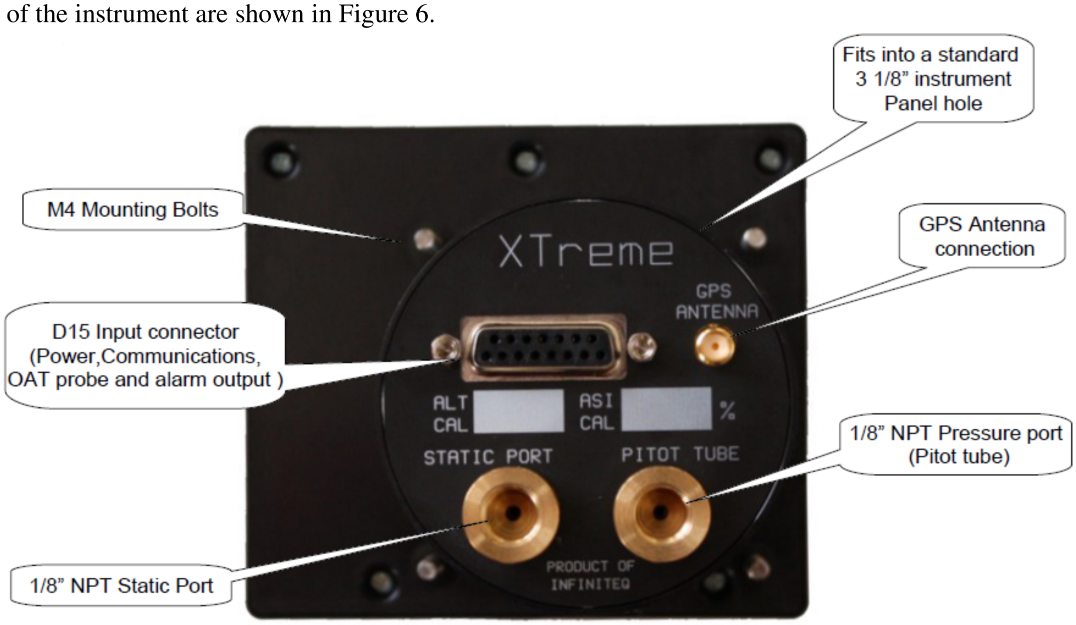

Figure 6. Rear Sensor Connections for the XTreme EFIS

The simplicity of the layout of connections to the EFIS allow for less wires and hoses, leading to a cleaner instrument panel backside. With all of these sensors hooked up to this one EFIS, the pilot is able to take one look at

the screen and know any performance data that he needs. With multiple screens to choose from on the single EFIS, the pilot can choose what data is shown, and can monitor as much or as little data as he wants. A few examples of the screens the pilot has to choose from are shown in Figure 7.

Figure 7. Examples of Different EFIS Screens

The upper screens show the main EFIS display, while at the same time showing engine data on the left screen, and heading data on the right screen. The lower screens show various engine data, in different formats. This particular EFIS also is connected to the GPS network, allowing for waypoints to be set to create a route for the aircraft.

With the XTreme EFIS system chosen, the layout of the instruments became much easier, but there were still many design decisions that had to be made. With the EFIS containing all of the instrumentation of the plane, it was discussed whether backup analog gages would be necessary. Due to the nature of the aircraft, which is a slow airplane where the pilot can fly by “feel”, it was felt that if the EFIS did fail, the plane could still be landed safely. Another decision that came up was to use fuses or circuit breakers. Although circuit breakers are easier to reset, they are heaver and more expensive, and so it was decided that we would simply use fuses. Yet another issue that arose was the problem of accessibility. Once the panel was made and connected, how would the instruments be accessed if there was a problem? Some solutions were looked into, such as folding the panel down for access, which would require large hinges and flexible cables, or having the dash lift up, which would have interference problems with the windshield. Due to the setup of the panel, as seen in Figure 8, we decided not to alter the panel for easy accessibility.

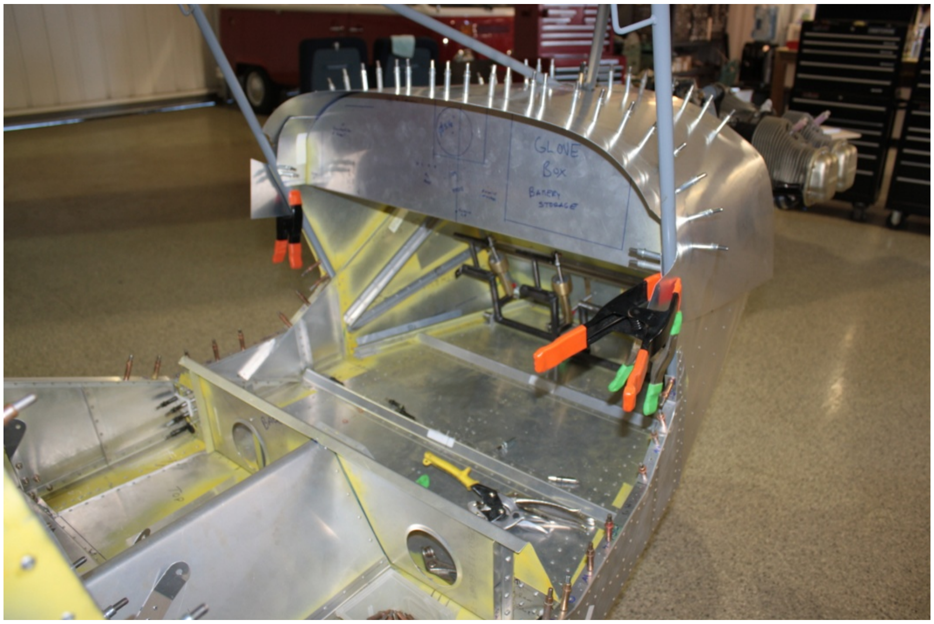

Figure 8. Basic Attachment of the Instrument Panel to the Fuselage

It would have been too difficult to modify the panel, and there is decent enough access to the back of the panel underneath just above the rudder pedals. One major issue that did arise was that the engine is hand started and contained magnetos that keep it running. Due to this, there is no battery for the engine, and so we had to figure out where the instrument power would come from. It was decided that, because the plane will only be flow for about an hour, a small rechargeable battery would be used to power the instruments. This battery could then be swapped out after each flight and replaced with a fresh battery.

Once some of these problems were addressed, the instrument panel could be laid out. The EFIS, radio, fuses, and switches were all located in the center of the panel, to allow easy access to both the passenger and pilot, as can be seen in Figure 9.


Figure 9. Layout of Instrument Panel

Due to the stick being in the center of the aircraft, the push/pull control rods were not placed in the center, for they would have hit the stick at their extended positions. Two sets of controls for these could have been placed on either side of the instrument panel, but this would have complicated the system. So these controls were placed on only the

left side of the panel, allowing the pilot to control these with his left hand and the stick with his right. These controls consist of the carburetor heat, fuel throttle, fuel mixture, and the cabin heat. Due to the amount of space left on the panel, a glove compartment was made on the right side, giving a place to store the battery that powers the instruments, a backup battery, and backup fuses. A close up of the center portion of the instrument panel can be seen in Figure 10.

Figure 10. Layout of Center of Instument Panel

In addition to the XTreme EFIS, the Flightline radio, fuses, magnetos switches, and power switch can be seen. The design considerations that went into the instrument panel were made throughout the building process, and resulted in an inexpensive, simple, and effective instrument panel.

III. Apparatus and Procedures

Figure 11. Wiring Bus, Splice Connectors, and Ring Terminals used in Making the Instrument Panel

The integration of the XTreme EFIS and its components as well as the Flightline FL-760 radio was a process of interpreting the wiring diagrams provided by all of the component's manuals and their respective connections. The main flow for the installation was providing power to all the components through their respective fuses, connecting the EFIS to the RDAC and its engine sensors, as well as to the AHRS unit, and connection of the radio to the headphones, antenna, and push to talk buttons.

The first order of business was connecting the system quickly without too much concern for wire organization so that we could make sure it functioned correctly before tightening and organizing all the wires behind the instrument panel. An initial instrument wiring diagram of this system was created in Solidworks, and is shown in Figure 12.

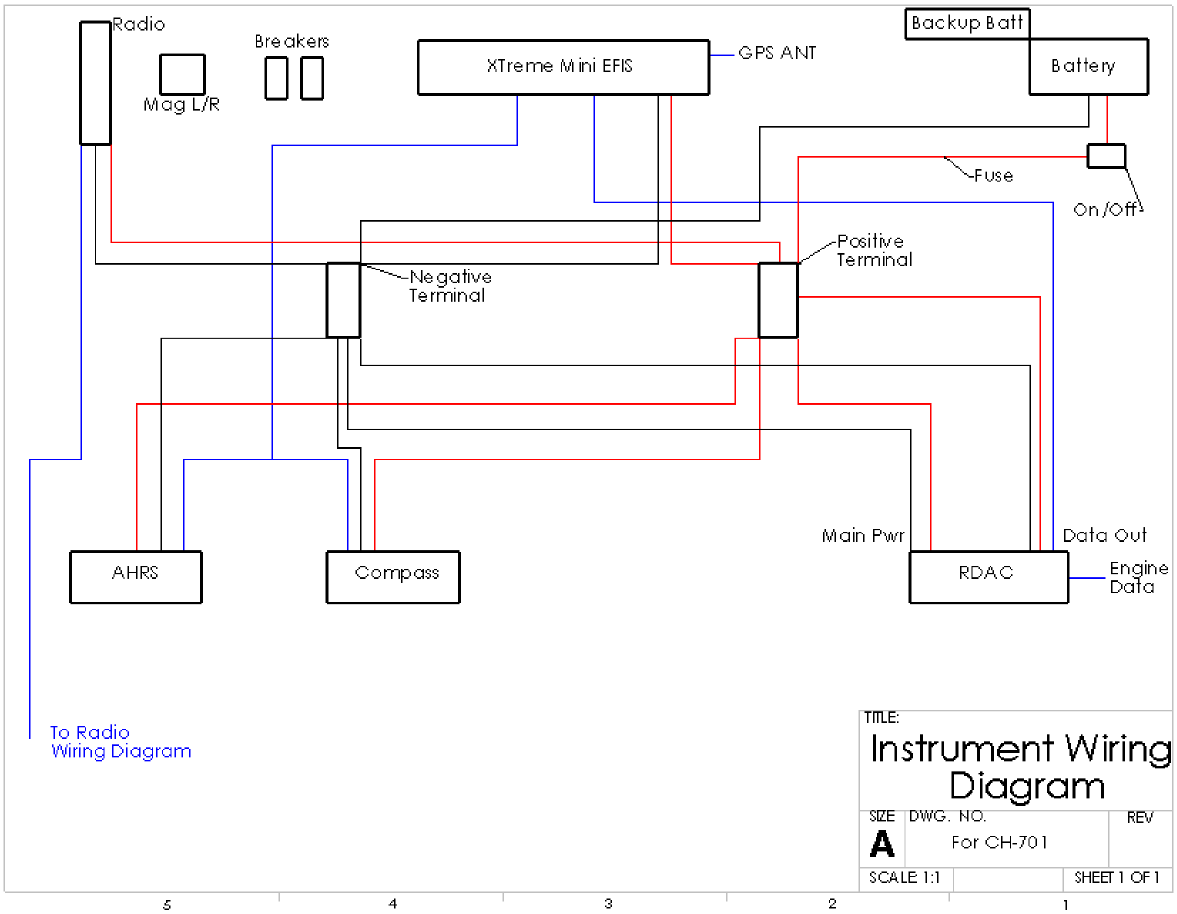

Figure 12. Initial Wiring Diagram for the Instrument Panel

After it was determined that the system functioned correctly, the wires were organized with zip ties and wall mounts to keep it all tidy. The procedure of connecting all the various components is as follows.

In order to have a convenient central connections bus, two 6 port connectors and one 4 port connector was attached to the firewall. This smaller connector was the main hub for the power for all the components. Wires were connected to the bus assembly with crimps with a loop in them so that they could be screwed in. If wires were attached to each other instead of to the bus, they were connected using a double crimp sleeve so that two wires could be inserted into it. After installing a connector to the battery pack, the positive side, or 'live' end was routed through a main power switch for the system, then split into two main circuits, one through a 3-amp fuse and one through a 1-amp fuse. Both of these both powered two separate sections of the power hub on the firewall, to which the EFIS, RDAC, radio, and AHRS were connected.

The AHRS was placed behind and above the pilots in a location thought to have the least amount of vibrations, on the plate that the AHRS was mounted on, the attitude sensor, the heading sensor, as well as the plugs for the headphones and microphones. The wires for all of these components were routed down along the side of the cockpit, and up into the main deck for the instruments. The manual for the AHRS unit in combination with a continuity tester allowed us to determine which wires connected to the back of the EFIS. Instead of connecting the wires directly

with crimps, they were mounted to the busses on the firewall so that disconnection and troubleshooting for the system would be easier later on in the airplanes life. The AHRS unit, comprised of the attitude and heading sensors, transmits its data over one wire only, using a protocol called airtalk. It talks to the two units at different times so that only one connection needs to be made between the two sensors and the EFIS central unit.

The radio connections followed a similar process to the AHRS unit, a manual allowed the determination of the correct wiring scheme. These connections were also established at the central bus for easy access. The wires connecting the radio equipment had shielding on it, as did many other connecting wires in the system, and it was usually connected to ground. Stripping and pulling apart the various wires, as well as winding the shielding into a single wire strand was an extremely common task. A push to talk switch was installed on the control stick and routed down, around, and into the instrument panel. Once the switch was connected, and a pair of headphones were plugged in, the radio was tested with an external unit to make sure the unit was functioning correctly. Since there are a pair of jacks for the pilot headphone/microphone and a pair for the copilot, we needed to make sure that we didn’t have the two switched, so we double checked and triple checked to make sure that the microphone attached to the pilot is the one transmitting across the radio. A button was installed in order to accommodate push to talk between the pilot and copilot only, but it was determined that the connection between pilot and copilot is voice activated, so there isn’t any switch operation necessary.

The RDAC unit was one of the more simple components to connect to the system, as it only had two power leads, as well as one data line that connected directly to the EFIS unit. Oil pressure sensor, oil temperature, RPM sensor (magnetometer), exhaust temperature and cylinder head temperature, were all connected directly to the RDAC, which was mounted inside the engine case to make wiring easy. The only wires that needed to pass through the firewall are the data and power lines for the RDAC.

V. Conclusion

There are clearly many benefits of having an electronic flight instrument system. Advancements for the EFIS technology are rapidly introducing new and exciting possibilities. There are now a multitude of companies that offer varying types of EFIS with their own pros and cons which work to accommodate what type and class of aircraft they will be utilized for. Production has begun to design and implement EFIS systems that are displayed directly on the windshield to decrease reaction time from having to look down at the instrument panel and allowing pilots to keep their eyes on the windshield. The simplification of including the instruments in a more organized manner, with fewer instruments displayed at a time gives the pilot the advantage of having less to look at and narrow down what is necessary for viewing for the different phases of the flight. This electronic display also increases the emphasis of critical flight conditions, making it extra noticeable of alerts and warnings.

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